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Relationship Between Corneal Astigmatism and Intraocular Pressure

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ABSTRACT

Aim of the work: this study aimed to investigate the relationship between the Intraocular Pressure(IOP) readings measured by Goldmaan Tonometry and the amount of corneal astigmatism in healthy young subjects and to assess the reliability of the measurements obtained with the instruments.

Method: intraocular pressure measurements were obtained by Goldmann Applanation Tonometer (GAT) (Haag-Streit International, Koeniz, Switzerland), while keratometry readings for corneal curvature were obtained by an Auto-Kerato-Refractometer (ARK-KR.8800, Topcon, Tokyo, Japan). An interval was kept between the keratometric measurements and the IOP measurements. The sequence of measurement was randomized with all participants. Three measurements were taken within ten minutes and the reading was set to one immediately after any measurement were taken.

Result: the average age of the volunteers was 22.4 ± 1.5 years (mean age ± SD; range: 20–26 years). Mean Intraocular Pressure (IOP) of the right and left eyes in the first visit (Paired t-test: P = 0.6471) and second visit (Paired t-test: P = 0.5805). The session one means GAT ; IOP was 16.48 ± 3.33 mmHg and 16.59 ±3.47mmHg (right and left eye respectively), while in session two it was15.714±3.10 mmHg and 15.82 ± 2.76 (right and left eye respectively) . The mean corneal astigmatism was -0.24 ± 1.48D, -0.38 ± 1.53 D, right and left respectively in the first visit and -0.34 ± 1.44D, -0.40 ± 1.64D right and left eye second visit respectively.

Conclusion: the GAT-IOP was less affected by the amount of corneal astigmatism and GAT-IOP was not significantly higher in eyes with greater corneal astigmatism and the repeatability results, although the differences were stastistically significant, they were not clinically significant.

Keywords: glucoma corneal astigmatism, Goldmann tonometry, auto-refractometer.

INTRODUCTION

When the drainage tubes (Trabecular meshwork) within the eye become slightly blocked, glaucoma can occur. Glaucoma can badly affect the eye to blindness. Early treatment of glaucoma can prevent eye damage [(1)].

When the fluid of the eye cannot drain properly, pressure builds up. This is called intraocular pressure. This can damage the optic nerve, which connects the eye to the brain and the nerve fibers from the retina (the light-sensitive nerve tissue that lines the back of the eye) [(2)]. The corneal astigmatism was determined as the dioptric difference between the steep and flat meridians. Corneal curvature is typically measured by keratometry or videokeratography.

Both methods have been shown to be repeatable in measuring spherical surfaces, such as steel balls, to within 0.25 diopter [(3)]. For normal human corneas, keratometry has been shown to be repeatable to within 0.87 D [(4)] and videokeratography to within 0.50 D [(5)]. Astigmatism is a minor condition of the eye that causes blurred vision. It occurs when the cornea is not a perfectly curved shape.

Most people who wear glasses have astigmatism. Intra Ocular Pressure (IOP) measurement is the base in the diagnosis and management of most of the ophthalmology diseases. For many years Goldmann Applanation tonometry (GAT) is the method that is used to measure the IOP through Imbert–Fick law, as the force required to applanate, is the same as the IOP times the applanated area (7.35 mm2) [(6)].

Also, **Goldmann** reported that central corneal thickness (CCT) could affect the IOP. However, it was reported that this method has some errors in the measurement IOP because of corneal thickness [(7)] corneal curvature, or the tear film [(8,9)] So, it is obviously that GAT-IOP readings are influenced by corneal astigmatism [0.25 to 0.67 mmHg per diopter (D)][(10,11)] .

PURPOSE

This study aimed to investigate the relationship between the Intraocular Pressure(IOP) readings measured by Goldmaan Tonometry and the amount of corneal astigmatism in healthy young subjects and to assess the reliability of the measurements obtained with the instruments.

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SUBJECTS AND METHODS

Eighty-four eyes of 42 healthy volunteers who had no previous history of the corneal disease or eye surgery were enrolled in this study. The average age of the volunteers was 22.4 ± 1.5 years (mean age ± SD; range: 20–26 years). Informed consent was obtained from all participants. Intraocular pressure measurements were obtained by Goldmann Applanation Tonometer GAT (Haag-Streit International, Koeniz, Switzerland), while keratometry readings for corneal curvature were obtained by an Auto-Kerato-Refractometer (ARK-KR.8800, Topcon, Tokyo, Japan). An interval was kept between the keratometric measurements and the IOP measurements. The sequence of measurement was randomized with all participants. Randomization of which eye was first measured was determined by a series of random numbers generated from the Microsoft Excel spread sheet. The patient was instructed to choose randomly any number from a group of multiple numbers. If the pick results in an odd number, the examiner starts with right eye measurements first and if even number, start with the left eye.

All mesurments were performed during a normal working day to minimize the effect of the diurnal curve[(12)]. For GAT measurements, subjects underwent IOP measurement, which was mounted on a slit lamp. A strip of fluorescein (Haag-Streit Ag, Ch-3098 Koniz, Switzerland) and a drop of 0.4% Oxybuprocaine (Novartis International AG, Basel, Switzerland) were instilled into each subject's eyes before taking measurements with their head properly positioned on the slit lamp. With the aid of the cobalt blue light of the slit lamp and ensuring that the bioprism touches the cornea in the center. The examiner looked into the tow half circles of the probe, making sure it touches the edges. Three measurements were taken within ten minutes and the reading was set to one immediately after any measurement was taken. Also, to assess the repeatability of the measurements, three consecutive measurements of IOP and corneal astigmatism were made with this device in 84 normal eyes at the same time on two different days, one week apart. Between-session repeatability was calculated.

The study was done after approval of ethical board of King Saud Bin Abdulaziz university

Statistical analysis

All statistical analysis was performed using the GraphPad Instat software (San Diego, CA, USA). The results were expressed as mean ± SD and a value of $p < 0.05$ was considered statistically significant. A paired Wilcoxon matched paired test was conducted to evaluate differences in corneal astigmatism of the right eye and left eye, and a paired student t-test conducted to compare IOP averages in the right eye and left eye of each subject.To assess the magnitude of the relationship between corneal astigmatism and intraocular pressure for each eye, we plotted a linear regression graph with a coefficient of correlation indicated. For repeatability between sessions of the two GAT and Keratometry measurements, we plotted a Bland-Altman scatter graph of mean difference against average IOP and average keratometry. This study was done within two season with a weak interval.

RESULTS

The statistical analysis of the intraocular pressure of 42 male patients enrolled in this study were as represented in **table1**, showing no statistically significant difference between mean IOP of the right and left eye in session one (Paired t-test: P = 0.6471) and session two (Paired t-test: P = 0.5805). The session one mean GAT IOP was 16.48 ± 3.33 mmHg and 16.59±3.47mmHg (right and left eye respectively), while in session two it was15.714±3.10 mmHg and 15.82 ± 2.76 (right and left eye respectively). Also, corneal astigmatism (**Table 2**), vertical and horizontal corneal curvatures (Table 3), did not vary significantly between the right and left eye of our subjects at a 0.05 level of significance.

Table 1. A paired student t-test analysis of intraocular pressure measurement values obtained by Goldmann Applanation Tonometer in session one versus session 2, with the 95% confidence intervals (CI)

		MEAN ± SD	MEAN DIFF.±SD	RANGE of Values	PROBABILITY	95% CI
GAT session 1	OD	16.48 ±	-0.0635 ± 1.0074	10 -	0.6471	15.4 –
	OS	16.59 ±3.47	0.1587 ± 0.9521	10 - 18	0.6471	15.5 –
GAT session 2	OD	15.714±3.0	0.0635 ± 0.8173	10 -	0.5805	14.75 –
	OS	15.817±2.7	-0.191 ± 0.755	11 -	0.5805	14.92 –

The mean corneal astigmatism was -0.24 ± 1.48D, -0.38 ± 1.53 D, right and left respectively in the first visit and -0.34 ± 1.44D, -0.40 ± 1.64D right and left eye second visit respectively.

Table 2. Wilcoxon matched-pairs signed-ranks test comparative analysis of right versus left eye corneal astigmatism readings as returned by Topcon RKT-8800 autoref/keratometry in sessions 1 and 2 with 95% confidence intervals (CI).

CORNEAL ASTIGMATIS		MEAN±SD	RANGE of VALUES	PROBABILITY	95% CI
Session 1	OD	-0.236 ±	-3.377 –	0.2821	-0.697 –
	OS	-0.3747 ±	-3.21 –	0.2821	-0.852 –
Session 2	OD	-0.338 ±	-3.38 –	0.5672	-0.787 –
	OS	-0.401 ±	-4.25 –	0.5672	-0.913 –

Table 3. Unpaired student t-test comparative analysis of Horizontal and Vertical meridians of right versus left eye as obtained by keratometry.

Keratomety		Horizontal		Probabilit	Vertical		Probability
		MEAN±SD	MEAN DIFF±SD	Horizontal	MEAN±S	MEAN	VERTICAL
ession 1	OD	2.69±1.78	-0.00016± 0.09	0.5492	42.92 ± 1.58	0.162±0.16	0.1256
	OS	2.73± 1.81	-0.03 ±0.08	0.5492	43.1± 1.73	0.0081± 0.174	0.1256
ession 2	OD	2.66 ± 1.79	0.01± 0.09	0.9007	42.66 ± 1.79	0.01 ± 0.09	0.9696
	OS	3.00 ± 1.58	-0.01± 0.075	0.9007	42.61 ± 1.79	0.002 ± 0.035	0.9696

The linear regression graph and Pearson correlation coefficient values for OD and OS in sessions one and two were shown in fig 1- fig 4. There was a weak, but insignificant positive correlation between mean GAT-IOP and amount of corneal astigmatism measured in the right eye ***(*r = 0.3, p = 0.0894*)***. GAT-IOP and amount of astigmatism in left eye **(r = 0.3, p = 0.0698)** in session one. This was consistent in session two measurements as mean GAT-IOP was weakly correlated with the amount of corneal astigmatism in the right eye **(r = 0.2, p = 0.2370).** However**,** this was not the same with session two measurements obtained in the left eye as the GAT-IOP readings returned a significant but weak positive correlation (r = 0.3, **p = 0.0307*)*** with the amount of corneal astigmatism.

Repeatability Analysis

A paired t-test analysis revealed that: in the horizontal meridian, there was no statistically significant difference (p=0.4447) in keratometry values obtained in the right eye were 0.02 ± 0.20, MD±SD; 95% CI:-0.039 to 0.009), between session one and session two measurements. Difference between K-readings obtained in the horizontal meridian of the left eye in session 1 and 2 (0.11 ± 0.57, MD± SD; 95% CI:-0.065 to 0.287) were also not statistically significant (p = 0.2086) in the vertical meridian, the difference between session1 and session 2 mean K- readings obtained in the right eye was approaching significant level (p = 0.06) on paired t test analysis with a mean difference ± SD of -0.08 ± 0.26 D (95% CI:-0.158 to 0.002) whereas that of the left eye was not significantly (p = 0.3915) different between sessions (0.08627±0.10, MD±SD; 95% CI: -0.1149 to 0.2874). For the GAT-IOP, measurements were statistically significantly higher (paired t-test: p <0.05) in the first session of right (0.77 mmHg;95% CI:0.04636 to 1.493) and left (0.77mmHg; 95% CI:0.0799 to 1.475) eyes as compared to the second session.

Although the differences were statistically significant, they were not clinically significant. Repeatability coefficient of the GAT was 1.97/1.87mmHg for right and left eyes in session one and 1.60 and 1.48 for the second session right and left eye respectively.

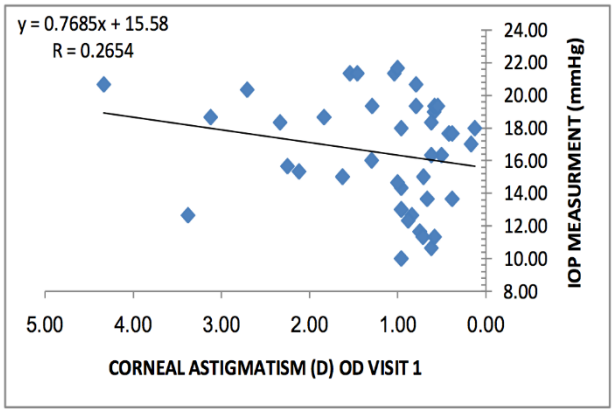

Fig 1

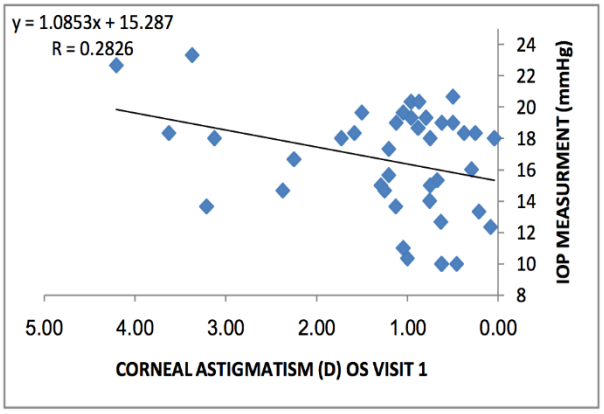

Fig 2

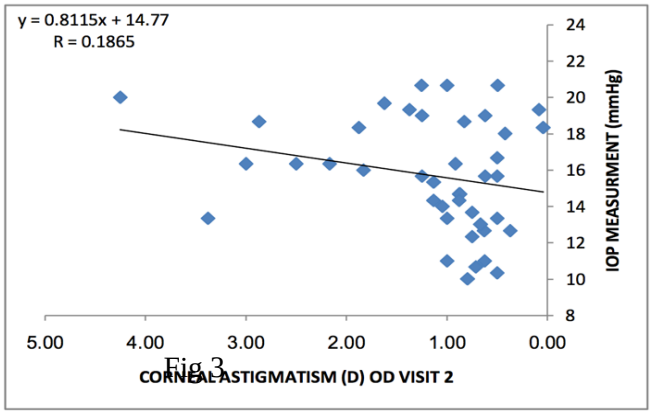

Fig 3

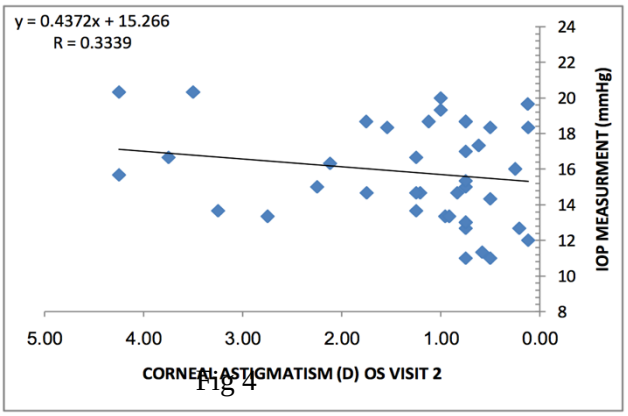

Fig 4

DISCUSSION

The Goldmann applanation tonometer (GAT) is currently the most widely used instrument for measuring IOP and it is considered the "gold standard." The GAT, however, has two disadvantages. First, the instrument probe must come in direct contact with the cornea, which can increase a patient's risk of infection. Second, use of the GAT requires a local anesthetic and some patients such as children were unwilling or unable to tolerate drug instillation.

Despite these inherent disadvantages, GAT is still the accurate method of determining IOP, thus its use in this study [6].

In this study, the corneal mean curvatures were not significantly different between the right and left eye ($P > 0.05$) of each subject, as were the GAT-IOP readings ($P > 0.05$), in both sessions. Overall, the IOP measurements in the right eye where between 10 and 23.3 mmHg, and in the left eye, it was between 10 and 20.7 mmHg, revealing that all of our subjects had GAT-IOP readings within the „normal" values in the absence of any other risk factor. We demonstrated that the mean value of GAT-IOP in the first session (16.48 ± 3.329, 16.59±3.477mmHg; OD and OS respectively) were slightly higher than the mean GAT-IOP in the second session (15.714±3.098, 15.817±2.7634mmHg; OD and OS respectively) which is in good agreement with the previous finding of **Hagishima *et al.*** [12] study with mean GAT-IOP reading of 14.2 ± 1.7mmHg. In contrast to the findings of Hagishma and cohorts [12]. We demonstrated that there was a weak, but insignificant, positive correlation between GAT-IOP and corneal astigmatism in both sessions in the right and left eye, except for the second session measurements of the left eye where this correlation was significant. No possible explanation for this could be given except for instrument mechanics. About GAT-IOP readings, the cornea at the flat meridian was applanated, and then that at the steep meridian was applanated, suggesting that a larger applanation force may be necessary for eyes with a larger amount of corneal astigmatism. Although **Goldmann *et al.*** considered

Attempting to overcome this dilemma by calculating the angle to the horizontal where the applanated area of an ellipse is exactly 7.35 mm [7], this may be contributed to higher GAT-IOP readings in eyes with greater corneal astigmatism. Several previous findings were in accordance with our present findings. A study of **Holladay *et al***. [10] included 12 eyes and they used analysis of variance and Pearson product-moment correlation. They stated that horizontal orientation led to an underestimation of approximately 1 mmHg for every 4 D of corneal astigmatism when they used only the normal, horizontal measurement . **Almubrad and Ogbuehi** [13] in study of 30 eyes they used linear regression analysis and they noticed an increase of 1 D in corneal curvature corresponded to an increase of 0.53 mmHg and **Rask *et al***. [11] demonstrated in a study of 50 eyes used linear regression analysis that there was not only a weak, but significant, correlation between astigmatism in 180 degrees and the IOP measured with a horizontal prism, but also a similarly significant correlation between astigmatism in 90 degrees and IOP measured with the prism in the vertical position, indicating that an increase of 1 D in corneal astigmatism leads to an increase of 0.58 to 0.67 mmHg (**Rask *et al***.) [11].

In the present study, the vertical meridian was consistently steeper than the horizontal meridian in both eyes in sessions 1 and 2. The mean horizontal corneal curvature measurements ranged from38.1 to 46.8D, while the mean vertical corneal curvature readings ranged from 40.0 to 47.8D. This demonstrated that corneal astigmatism in our subjects mostly followed the with-the-rule astigmatism pattern (vertical meridian being steeper than the horizontal meridian). The mean corneal astigmatism observed in the left eye was slightly higher (-0.3747 ± 1.53D /-0.401 ± 1.644D) than that observed in the right eye (-0.236 ± 1.48D / -0.338 ± 1.44D) in sessions 1 and 2.

To assess repeatability of the measurements, we made three consecutive measurements of GAT-IOP and corneal curvature with these devices in 84 normal eyes at the same time of day, One week apart showing that the repeatability coefficients were ± 1.92 mmHg and ± 1.54 mmHg first and second session respectively of GAT-IOP. For the corneal curvature in the two meridians, it was ± 0.17D in both sessions for the horizontal meridian, and ± 0.33D/ ± 0.13D first and second session of the vertical meridian. This means that corneal curvatures obtained by the RKT 8800 were more repeatable in the horizontal meridian than in the vertical meridian Studies have also shown good repeatability for the GAT. Ogbuehi and Almubrad reported repeatability coefficients of ± 1.8 and ± 2.1mmHg in session one and two of

their GAT-IOP measurements in 66 normal adults, while two other studies reported ± 2.5 mmHg and ± 3.70 mmHg. In our study, the repeatability of the GAT-IOP was. This is similar to that reported by **Almubrad, Ogbuehi[13].**

Rask *et al.* [17] , **Tonnu, P[14]** and **Hagishima[12]** stated that clinical factors other than corneal thickness and astigmatism might contribute to measurement errors in the GAT-IOP readings. It has also been shown that central corneal thickness and the tear film may impact the IOP measurements especially those made by GAT [7].

We did not perform CCT measurement which was a major limitation of this study and we cannot deny the possibility that CCT may affect the IOP measurement in our study. The small number of sample subjects was also a limitation of our study. We recommended further investigation with greater number of subjects and in subjects with high astigmatism to determine the exact effect of corneal curvature and CCT on these IOP measurements with GA.

CONCLUSION

In conclusion, we demonstrated that the GAT-IOP were less affected by the amount of corneal astigmatism and that GAT-IOP was not significantly higher in eyes with greater corneal astigmatism though there was a weak positive correlation. For the repeatability results, although the differences were stastistically significant, they were not clinically significant.

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